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## INTRODUCTION

### STEM ENGAGEMENT

[NASA's](#) journeys have propelled technological breakthroughs, pushed the frontiers of scientific research, and expanded our understanding of the universe. These accomplishments, and those to come, share a common genesis: education in science, technology, engineering, and math. In [NASA STEM Engagement](#), we deliver tools for students and educators to learn and succeed. We seek to: Create unique opportunities for a diverse set of students to contribute to NASA's work in exploration and discovery; Build a diverse future STEM workforce by engaging students in authentic learning experiences with NASA's people, content and facilities, and; attract diverse groups of students to STEM through learning opportunities that spark interest and provide connections to NASA's mission and work. NASA STEM Engagement strives to increase K-12 involvement in NASA projects, enhance higher education, support underrepresented communities, strengthen online education, and boost NASA's contribution to informal education. The intended outcome is a generation prepared to code, calculate, design, and discover its way to a new era of American innovation.

Lunabotics aligns with the following strategic initiatives:

1. NASA STRATEGIC PLAN 2022 - Goal 4 Enhance Capabilities and Operations to Catalyze Current and Future Mission Success; 4.3 Build the next generation of explorers (OSTEM strategically owns Objective 4.3)
2. NASA Strategy for STEM Engagement (Science, Technology, Engineering and Math), April 29, 2020 as follows:

#### STRATEGIC GOAL 1.0: Create unique opportunities for a diverse set of students to contribute to NASA's work in exploration and discovery.



##### OBJECTIVES:

- 1.1 Provide student work experiences that enable students to contribute to NASA's missions and programs, embedded with NASA's STEM practitioners.
- 1.2 Create structured and widely-accessible, experiential learning opportunities for students to engage with NASA's experts and help solve problems that are critical to NASA's mission.

#### STRATEGIC GOAL 2.0: Build a diverse future STEM workforce by engaging students in authentic learning experiences with NASA's people, content and facilities.



##### OBJECTIVES:

- 2.1 Develop and deploy a continuum of STEM experiences through authentic learning and research opportunities with NASA's people and work to cultivate student interest, including students from underrepresented and underserved communities, in pursuing STEM careers and foster interest in aerospace fields.
- 2.2 Design the portfolio of NASA STEM engagement opportunities to contribute toward meeting Agency workforce requirements and serving the nation's aerospace and relevant STEM needs.



## **ACCREDITATION BOARD FOR ENGINEERING AND TECHNOLOGY (ABET)**

One of the goals of Lunabotics is to introduce students to the [ABET](#) experience by aligning the events to those student outcomes. ABET is a nonprofit, ISO 9001 certified organization that accredits college and university programs in applied and natural science, computing, engineering and engineering technology. ABET accredits college and university programs in the disciplines of applied and natural science, computing, engineering and engineering technology at the associate, bachelor's and master's degree levels. ABET is the basis of quality for STEM disciplines all over the world. Schools do not have to be ABET accredited to participate.

### **1. CRITERIA 3. STUDENT OUTCOMES:**

1. For baccalaureate degree programs, these student outcomes must include, but are not limited to, the following learned capabilities:
  - a. an ability to select and apply the knowledge, techniques, skills, and modern tools of the discipline to broadly-defined engineering technology activities;
  - b. an ability to select and apply a knowledge of mathematics, science, engineering, and technology to engineering technology problems that require the application of principles and applied procedures or methodologies;
  - c. an ability to conduct standard tests and measurements; to conduct, analyze, and interpret experiments; and to apply experimental results to improve processes;
  - d. an ability to design systems, components, or processes for broadly-defined engineering technology problems appropriate to program educational objectives;
  - e. an ability to function effectively as a member or leader on a technical team;
  - f. an ability to identify, analyze, and solve broadly-defined engineering technology problems;
  - g. an ability to apply written, oral, and graphical communication in both technical and non-technical environments; and an ability to identify and use appropriate technical literature;
  - h. an understanding of the need for and an ability to engage in self-directed continuing professional development;
  - i. an understanding of and a commitment to address professional and ethical responsibilities including a respect for diversity;
  - j. a knowledge of the impact of engineering technology solutions in a societal and global context; and;
  - k. a commitment to quality, timeliness, and continuous improvement.

## **MEDIA ADVISORY**

"All visitors to Lunabotics at the Kennedy Space Center give permission to be photographed/videotaped by NASA or its representatives for potential use in future media products, unconditionally releasing NASA and its representatives from any claims and demands."

## **WAIVER**

Participants hereby waives any claims against NASA, its employees, its related entities, (including, but not limited to, contractors and subcontractors at any tier, grantees, investigators, volunteers, customers, users, and their contractors and subcontractors, at any tier) and employees of NASA's related entities for any injury, death, or property damage/loss arising from or related to the NASA's Lunabotics Challenge, whether such injury, death, or property damage/loss arises through negligence or otherwise, except in the case of willful misconduct.

## **MISSION IMPACT**

Be advised the [Kennedy Space Center](#) is an active launch range. NASA may change deadlines, deliverables and or cancel the event itself.

## **SOCIAL MEDIA**

The Lunabotics [Facebook](#) page allows us to post notifications to the teams and the teams to communicate with each other, post photos, etc. Remember to “Like Us”.

## **WHY THE MOON**

The Moon was the first place beyond Earth humans tried to reach as the Space Age began in the late 1950s. More than 100 robotic explorers from more than half a dozen nations have since sent spacecraft to the Moon. Nine crewed missions have flown to the Moon and back. The former Soviet Union logged the first successes with its Luna program, starting with Luna 1 in 1959. NASA followed with a series of robotic [Ranger and Surveyor spacecraft](#) that performed increasingly complex tasks that made it possible for the first human beings to walk on the Moon in 1969. Twenty-four humans have traveled from the Earth to the Moon. Twelve [walked on its surface](#). The last human visited the Lunar surface in 1972.

The skills developed in Lunabotics apply to other high technology industries that rely on the systems engineering principles. These industries will create a workforce posed to lead a new space-based economy and add to the economic strength of our country. NASA directly benefits from this challenge by annually assessing student designs and data the same way it does for its own, less frequent, prototypes. Encouraging innovation in student designs increases the potential of identifying clever solutions to the many challenges inherent in future Artemis missions.

*“Good for NASA, Good for America, Good for All of Us”*



## 1. LUNABOTICS 2023

Since 2010, NASA's Lunabotics competition has provided college students from around the country an opportunity to engage with the NASA Systems Engineering process by designing and building robotic Lunar excavators capable of mining regolith and icy regolith simulants. For more than a decade, NASA has been able to gather valuable data about necessary excavation hardware and surface locomotion processes that can be implemented as the agency prepares to return to the Moon through the Artemis program.

It is time to offer a new design / build event that reflects the upcoming challenges astronauts and robots will face when living and working on the Lunar surface. Throughout the 2023 competition cycle, Lunabotics will undergo a transition to a new Artemis Student Challenge to be announced in the summer of 2023. This new challenge will provide NASA valuable information for the design of robots and innovative construction techniques for Lunar and Martian environments. Major gaps exist between the functional capabilities and the technologies necessary for Lunar surface construction, and the requirements needed to narrow these gaps are in development and will support the long-term presence on the Moon, also known as "Infrastructure to Stay". Once identified, NASA will seek input from American academia to find new and innovative ways to apply existing or develop new technologies to meet Artemis Program requirements.

In preparation for this new phase, Lunabotics 2023 will be a virtual challenge to allow NASA to evaluate and re-formulate the Lunabotics competition to be relevant to the Artemis lunar program future needs. The on-site competition at the Kennedy Space Center may resume in 2024 with a new format.

### 1.1 THE CHALLENGE FOR 2023

While NASA Kennedy Space Center will not be offering an on-site competition in 2023, it is still necessary to design, fabricate, assemble and operate a Lunabot.

The "Proof of Life" video recording shall serve as a verification that the Lunabot is fully functioning.

The Lunabot shall drive on a simulated arena and excavate simulated icy regolith buried under an overburden of granular material, then it must return to the starting site and deliver the granular material to a simulated receiving hopper. More details are provided in "Proof of Life, Arena and Operations Criteria". This is a two-semester, virtual challenge, designed to educate college students in the application of the NASA Systems Engineering process. The events are as follows:

1. Project Management Plan
2. Systems Engineering Paper
3. Public Outreach Report
4. Presentation and Demonstration (optional)
5. Proof of Life Video

### 1.2 CODE OF CONDUCT

Lunabotics is a National Aeronautics and Space Administration Artemis Student Challenge and is held in a positive and safe environment. Competitors shall be professional, courteous and respectful to all individuals. Students and faculty shall conduct themselves with integrity as to the spirit and intent of the

rules, rubrics and regulations. Violation of the intent of a rule is a violation of the rule itself. The Chief Judge and Project Manager's decision is final and shall prevail.

### 1.3 ROLES AND RESPONSIBILITIES

It is the responsibility of the Chief Judge and Project Manager to ensure the integrity of the challenge as to the interpretation and enforcement of the rules and rubrics in the Guidebook. The goal is to apply the content of the Guidebook equally to the competitors without passion or prejudice. The Lead Judges are responsible for creating the rules and rubrics and judging the deliverables received from the teams for their events. In matters associated with the overall Lunabotics Challenge, the Chief Judge and Project Manager's decision is final.

### 1.4 DISPUTES

The Chief Judge and the Project Manager shall review and issue a decision on the dispute. The Chief Judge and Project Manager's decision is final and shall prevail.

### 1.5 FREQUENTLY ASKED QUESTIONS (FAQ) AND HELP

It is the team's responsibility to monitor the Lunabotics [Website](#) for notices, updates, feedback requests and responses to FAQ's. The Guidebook and the FAQ's shall be read together as one document. Lunabotics will answer questions relevant to this year's challenge itself. Responses will be posted to the NASA Lunabotics website. There will be no response to requests for information already contained in the Guidebook or to waive a deadline, rule or rubric. If things go South ... and they may, reach out to the Lunabotics Team, if possible, together we will work on a resolution. Do not wait until the day of or the day before a deadline, there will be no time for problem resolution. Team Leads submit your questions with your name, school name and cite the relevant rule/paragraph number to the [FAQ](#) address.





## 2. EVENTS, DELIVERABLES AND DEADLINES

It is your responsibility to comply with the following requirements, you are encouraged to put a second set of eyes when reviewing all your work items. Do not wait until the day before or day of a deadline to upload your files, allow for delays, errors, lockouts, etc. There will not be a second opportunity to upload your work.

In accordance with the rules and rubrics, a team shall be removed from the challenge by failing to meet the requirements in this section.

### 2.1 EVENTS

Lunabotics is made up of the following virtual events:

1. Project Management Plan
2. Systems Engineering Paper
3. Public Outreach Report
4. Presentation and Demonstration (optional)
5. Proof of Life Video

### 2.2 DELIVERABLES AND DEADLINES

Deliverables are due before **11:00 P.M., Eastern Time** on the dates listed below:

LUNABOTICS DELIVERABLES	UPLOAD START DATE	UPLOAD END DATE
<b>APPLICATION</b>		
1. NASA Gateway - Team Lead starts the application process and then invites student members and faculty advisor to apply within the NASA Gateway system.	Wed Sep 14, 2022	Wed Oct 19, 2022
2. <u>Upload the following item(s) as one PDF File:</u> (1) Statement from Supervising Faculty; and (2) Statement of Rights of Use.		
3. <u>Upload the following item(s) as one PDF File:</u> Project Management Plan (one PDF document).		
<b>CHALLENGE</b>		
1. <u>Upload the following item(s) as one PDF File</u> Public Outreach Report.	Wed Feb 08, 2023	Wed Feb 15, 2023
<b>1.Upload the following item(s) as one PDF File</b> Proof of Life YouTube Link (ex: paste the link on a Word document, save as a PDF file and upload the file).	Wed Mar 22, 2023	Wed Mar 29, 2023
<b>2. Upload the following item(s) as one PDF File</b> Systems Engineering Paper.		
3. (OPTIONAL) <u>Upload the following item(s) as one PDF File:</u> Each school will be notified of the platform, date and time of this event. See the Rubric.		

The team lead will be the responsible party to upload the deliverable PDF files to Gateway. When you name your deliverable PDF files, use the following format before uploading your files to Gateway, School Name\_ XXXX:

1. Upload (1) Statement from Supervising Faculty and (2) Statement of Rights of Use (one PDF file).  
School Name\_DOCS
2. Upload Project Management Plan (one PDF file).  
School Name\_PMP
3. Upload Systems Engineering Paper (one PDF file).  
School Name\_SEP
4. Upload Public Outreach Report (one PDF file).  
School Name\_POR
5. (OPTIONAL) Upload Presentation and Demonstration Slides for your virtual presentation. Each school will be notified of the platform, date and time of this event (one PDF file).  
School Name\_PAD
6. Upload Proof of Life YouTube Link (one PDF file), paste the link on a word document, convert to a PDF and name it as follows:  
School Name\_POL

## 2.3 EVENT POINTS

The events and maximum points as assigned:

1. Project Management Plan	10
2. Systems Engineering Paper	25
3. Public Outreach Report	15
4. (OPTIONAL) Presentation and Demonstration	25
5. Proof of Life Video	50

## 2.4 WINNER OF THE GRAND PRIZE

The winning team shall compete in all the events, submit the required deliverables as stated and score the most points, a cumulative of the scores in all the events.



## 3. ELIGIBILITY, APPLICATION AND TEAM SELECTION

### 3.1 ELIGIBILITY

#### 1. Institution / Team

1. The institution shall be an accredited post high school, vocational / technical school, college or university located in the United States, its Commonwealths, territories or possessions.
2. Institutions may be permitted to have more than one team at NASA's discretion. Each team must have its own deliverables and working robot(s). Students can only participate on one team. Each team must have their own individual faculty advisor; faculty can only serve as an advisor for one team.
3. The team shall be comprised of enrolled undergraduate and graduate students and shall include at least two undergraduate students.
4. The number of students on the team is at the discretion of the faculty advisor.

#### 2. Students

1. Students shall be 18 years old at student registration. Age and enrollment verification may be requested.
2. Students shall be currently enrolled and in good standing with the school. Students who have graduated in the same semester/quarter as this challenge are eligible to be on the team.
3. Students shall be from the same school as the team.

#### 3. Supervising Faculty / Advisor

1. The school shall assign a supervising faculty advisor who is 21 years and authorized to represent the school to NASA.

### 3.2 APPLICATION

#### [NASA Gateway OSTEM Application Website](#)

You are advised to start the application/registration process as soon as feasible **after the "Upload Start Date"**. You are advised not to wait until the last days or day of a deadline to upload your files.

For more information on how to navigate the [NASA Gateway OSTEM Application Website](#) see **"Appendix A. Gateway Team Application Instructions"** at the end of the Guidebook. The Team Lead starts the team application process and then invites students and faculty advisor(s) to apply within the website.

When you run into an issue on the NASA Gateway OSTEM application website, send your inquiries to the website [Help Desk](#). You may encounter a one or two-day turnaround time on responses to your inquiries. Do not contact Lunabotics about issues on the website, we do not own the website, we cannot unlock your account(s), we cannot trouble shoot issues, etc.

Before you upload your PDF File(s), put a second set of eyes on what you are uploading, ensure you are uploading the correct file(s). There are issues involved in deleting, changing, etc. files. This process also takes time and if you are doing this near a looming deadline, you may miss the upload window. **You cannot "delete" a file from the Gateway system. Lunabotics will review the most recent deliverable file that is received prior to the deadline listed in the Guidebook.**

Get your document(s) together:

**1. Statement of Supervising Faculty**

A statement of support from a faculty advisor indicating a willingness to supervise and work with the team during all stages of the activity. There will be no consideration for teams working without a faculty advisor. The faculty advisor must also sign off on the cover of all deliverables as evidence he/she has seen the application and approves of the submission. The following statement should appear on an institution letterhead and include the signature of the faculty advisor:

As the faculty advisor for a team of higher education students from \_\_\_\_\_ institution, I concur with the concepts and methods by which the students plan to compete in “NASA Lunabotics”. I will ensure the student team members complete all project requirements and meet deadlines in a timely manner. I understand any default by this team concerning any project requirements (including submission of final report materials) could adversely affect selection opportunities of future teams from their institution.

\_\_\_\_\_  
Signature and Date

**2. Statement of Rights of Use**

These two statements grant NASA, acting on behalf of the U.S. Government, rights to use the team’s technical data and design concept, in part or in entirety, for government purposes. This statement is not required. However, teams with a Statement of Rights of Use will receive greater consideration in the application selection. If choosing to include these statements, ALL team members and faculty advisors must sign. The statements read as follows:

As a team member for a(n) application entitled “NASA Lunabotics” proposed by a team of undergraduate students from \_\_\_\_\_ university/college, I will and hereby do grant the U.S. Government a royalty-free, nonexclusive and irrevocable license to use, reproduce, distribute (including distribution by transmission) to the public, perform publicly, prepare derivative works, and display publicly, any data contained in this application in whole or in part and in any manner for Federal purposes and to have or permit others to do so for Federal purposes only.

As a team member for a(n) application entitled “NASA Lunabotics” proposed by a team of undergraduate students from \_\_\_\_\_ university/college, I will and hereby do grant the U.S. Government a nonexclusive, nontransferable, irrevocable, paid-up license to practice or have practiced for or on behalf of the United States an invention described or made part of this application throughout the world.

**3. Project Management Plan**

See the rubric.

The team lead will be the responsible party to upload the deliverable PDF files to Gateway. When

you name your deliverable PDF files, use the following format before uploading your files to Gateway:

Submit (1) Statement from Supervising Faculty; and (2) Statement of Rights of Use (one PDF file).  
School Name\_DOCS

Submit Project Management Plan (one PDF file).  
School Name\_PMP

Use the same school name for each uploaded deliverable, using a different name may lead to deliverables not being uploaded correctly.

NASA reserves the right to question, accept or reject any letter if submitted by a party not authorized to represent the institution in question.

### 3.3 TEAM SELECTION

The number of teams in this challenge is not predetermined but is based on their documents uploaded and the scores and overall quality of the Project Management Plan received. Teams will receive an email notification as to whether they have been accepted or not accepted to the challenge.





## 4. RUBRICS

Teams shall submit a complete deliverable based on the rubric presented. A partial deliverable shall be rejected and the team shall be removed from the challenge. Remember some requirements are purposely vague, we want the teams to do the research and provide their rationale.

1. 4.1 Project Management Plan
2. 4.2 Systems Engineering Paper
3. 4.3 Public Outreach Report
4. 4.4 Presentations and Demonstrations (optional)

### 4.1 PROJECT MANAGEMENT PLAN

**Resources available:**

A video series introducing the key project management and systems engineering products and how to apply them to your project can be viewed [Here](#).

1. Each team shall submit a complete Project Management Plan (PMP) electronically in one PDF file.
2. This is an initial plan. As you execute your project, things will change and your project will evolve, which is okay and expected. In your Systems Engineering Paper you can discuss the changes to your plan and how your project adapted.
3. Include your school name on the PMP.
4. Maximum length of the plan is 5 pages. If you include a cover page, it will not count towards the page limit. **Any content over 5 pages will not be judged.**
5. Format: The Project Management Plan shall be formatted professionally, organized clearly so that each required rubric element is easy to find, with correct spelling and grammar, with text no smaller than size 12 point font in the main body, with text no smaller than size 9 point font in graphics and tables, and using professional margins.

Scoring Rubric - Project Management Plan	
Element	Points
<p><i>Initial Project Schedule</i></p> <p>Provide a Gantt Chart or equivalent that shows the project's major due dates and events to include at least the five items listed below. Discuss these only as needed.</p> <ol style="list-style-type: none"> <li>1. Start Date</li> <li>2. Completion Date: (after project decommissioning; this is the date when you have disposed of your robot system after the challenge; for example, you hand the system over to next year's team, dispose of it or other)</li> </ol>	<p><b>There are 3 points total for 6 elements</b></p>

<p>3. Major review milestones: as a minimum, these must include</p> <ul style="list-style-type: none"> <li>○ Systems Requirements Review</li> <li>○ Preliminary Design Review</li> <li>○ Critical Design Review</li> <li>○ others may be identified as you find appropriate</li> </ul> <p>4. Product delivery dates to the Lunabotics Engineering Challenge, including as a minimum</p> <ul style="list-style-type: none"> <li>○ delivery of Systems Engineering Paper,</li> <li>○ the planned date to submit “Proof of Life”</li> </ul> <p>5. Important milestones related to Project Cost Budget and Technical Performance Measurement budget as identified in the Initial Project Budget and Initial Technical Performance Measurement budget sections of your Project Management Plan. (Optionally, you may also identify any major Systems Engineering activities in your Initial Project Schedule.)</p> <p>6. Discuss how you will manage the evolution of the schedule during the life of the project (how often and when you plan to review the project schedule, and how you plan to adapt to schedule slips or schedule advance opportunities).</p>	
<p><i>Initial Project Cost Budget</i></p> <p>Provide an estimate of the total project cost, inclusive of all possible costs. Provide a Table of Major Budget Categories and Items including the following list items as a minimum. Discuss only as needed.</p> <p>1. Breakdown of total project cost estimate for at least the following major items. (Total should add up to the estimate of the total project cost.)</p> <ul style="list-style-type: none"> <li>a. Cost estimates for elements in the earliest level System Hierarchy</li> <li>b. Labor costs, if any</li> <li>c. Material costs for challenge (for production and completion of Lunabotics deliverables)</li> <li>d. Travel costs to KSC</li> </ul> <p>2. Critical scheduling milestones for budget items or other categories if any. (These should be reflected in item 5 for the Initial Project Schedule; for example, dates funds will be needed, planned activities to raise funds, or others)</p> <p>3. Discuss how you will manage the evolution of the budget during the life of the project (how often you plan to review</p>	<p><b>There are 3 points total for 3 elements</b></p>

<p>your project budget and when, and how you plan to adapt to budget shortfalls or possible cost savings should they occur).</p>	
<p><i>Project Technical Objectives</i></p> <p>List and discuss the specific technical criteria or characteristics that your team intends to achieve (typically some technical parameter or measure you want to minimize or maximize, increase to some limit, or decrease to some limit) in your system design and operations to win the competition. These provide the technical direction and focus for the entire team in design and operations. For example: you might choose to minimize mass, or maximize automation, or maximize collection of icy regolith simulant, or minimize bandwidth, or some combination of these (or any other criteria or combination of criteria) to produce a system that will win the competition.</p>	<p><b>There is 1 point for 1 element</b></p>
<p><i>Initial Technical Performance Measures (Technical Budgets)</i></p> <p>Provide Table of Technical Performance Measures that you deem are important to your design approach (for example, mass, size, bandwidth, speed, or others) including the following as a minimum. Discuss only as needed.</p> <ol style="list-style-type: none"> <li>1. Identification of Technical Performance Measures</li> <li>2. Initial Target for each Technical Performance Measure to be achieved by the challenge</li> <li>3. Allocation of each Technical Performance Measure across the elements of the earliest System Hierarchy (should combine to the total at the highest level)</li> <li>4. Discuss any critical schedule milestones for achieving critical technical performance levels (for example, decision points in the design process where if you are unable to achieve the desired level you would change the design). (These should be reflected in item 5 for the Initial Project Schedule.)</li> <li>5. Discuss how you will manage the evolution of the Technical Performance Measurement budgets during the life of the project (how often you plan to review current technical budget item values, and how you plan to adapt to performance shortfalls or exceedances should they occur).</li> </ol>	<p><b>There are 3 total points for 5 elements</b></p>

**Project Management Plan (PMP) Tip #1**

Make sure your Gantt Chart (if using) and tables are readable if you are providing them to satisfy a rubric element. If we can't read it, we can't give you points. If you provide graphics with unreadable (less than 9-point text as viewed in the pdf) text, make sure the information to satisfy the rubric elements are discussed in the main body (at least 12-point font).

**Project Management Plan (PMP) Tip #2:**

Initial Project Schedule: Major Reviews

Make sure at least 3 show up on your schedule: SRR, PDR, and CDR. If you are using an alternate review instead of SRR, PDR, and CDR, then identify in the discussion the name of the review that replaces each.

**Project Management Plan (PMP) Tip #3:**

Developing any management plan boils down to two things: making decisions and writing them down. It's important to document those decisions at the beginning of the project and share with your team. Update your plan as you learn more and your project progresses. The Project Management Plan rubric identifies an important subset of the decisions you will have to make in your Lunabotics project planning process, and simply asks you to tell us what those specific decisions were.

**Project Management Plan (PMP) Tip #4:**

Initial Project Budget: Budget evolution

As your design matures, you will learn more about how much your project is to actually going to end up costing. To be sure you don't run out of money before the end of the project, set up periodic reviews of your cost budget. In case your costs are much greater (or much less) than you expect, decide at the beginning of the project how you will address budget shortfalls, and what you will do with budget excesses. Don't forget to make these decisions and discuss them in your PMP.

**Project Management Plan (PMP) Tip #5:**

Initial Technical Performance Measures (TPM): Allocation to System Hierarchy

The system hierarchy is the backbone of your project. At the very start of a project, it may only consist of two levels. That early decomposition allows you to allocate how much time you plan to spend on each sub-element in the hierarchy, how much money you plan to spend on each sub-element, and how much of the technical performance each sub-element will have to provide so the system can accomplish the mission. As your design matures, these early allocations guide you through the design process to deeper levels in the system hierarchy, and enable sub-allocations at these new levels. And of course, you may learn things in the design process that might change even those earliest allocations. There is an example of allocations down through the system hierarchy in SE Video 2: 'The Central Elements of Project Management'. That video describes budget allocation; the approach is similar for mass and other TPM allocations. Don't forget to include the TPM allocations in your PMP.



## 4.2 SYSTEMS ENGINEERING PAPER

### Resources available:

- A video series introducing the key products and techniques of systems engineering and how to apply them to your project can be viewed [Here](#).
  - As one example, undergraduate course materials in systems engineering are available [Here](#).
1. Each team shall submit a complete Systems Engineering Paper electronically in one PDF file.
  2. The purpose of the Systems Engineering Paper is for the team to demonstrate how they used the systems engineering process in designing, building, and testing their robot.
  3. A minimum score of 20 out of 25 possible points must be achieved to qualify to win in this category. In the case of a tie, the judges will choose the winning Systems Engineering Paper. The Judges' decision is final.

Scoring Rubric - Systems Engineering Paper	
Element	Points
<p><i>Content</i></p> <p>1. <u>Format</u>: Provide a cover page. The cover page shall include: team name, title of paper, full names of all team members, university name, and faculty advisor's full name.</p> <p>The Systems Engineering Paper shall consist of a maximum of 25 pages not including the cover page, title page, table of contents, and references pages. <b><i>Only the first 25 pages of the paper will be judged.</i></b></p> <p>The Systems Engineering Paper shall be formatted professionally as if for submission to a professional journal: organized clearly so that each required rubric element is easy to find; with correct grammar and spelling; with text no smaller than size 12 point font in the main body and appendices; text no smaller than size 9 point font in graphics and tables; using professional journal margins; and single spaced.</p> <p>2. <u>Faculty Signature</u>: The cover or title page shall include the signature of the sponsoring faculty advisor and a statement that he/she has read and reviewed the paper prior to submission to NASA.</p> <p>3. <u>Reason for using Systems Engineering</u>:</p>	<p><b>There are 3 points for 3 elements, one point each</b></p>



<p>A statement shall be included early in the main body explaining the reason the team used systems engineering in this Engineering Competition (beyond that it is required). (For example: What benefit did it provide? How was systems engineering valuable to your project? You may have other reasons.)</p>	
<p><i>Project Management Merit</i></p> <p>1. <u>Project Technical Objectives:</u> List and discuss the specific technical criteria or characteristics that your team intends to achieve (typically some technical parameter or measure you want to minimize or maximize, increase to some limit, or decrease to some limit) in your system design and operations to win the competition. These provide the technical direction and focus for the entire team in design and operations. For example: you might choose to minimize mass, or maximize automation, or maximize collection of icy regolith simulant, or minimize bandwidth, or some combination of these (or any other criteria or combination of criteria) to produce a system that will win the competition. [1 point]</p> <p>2. <u>Is your system a New Design or Design Update:</u> Clearly identify the new elements in this competition year's robot system. (Either state that the robot system is an entirely new design, or identify the specific subsystems or components that were changed on a previous robot system. Provide the system hierarchy for the previous robot system and identify which items were changed for this year's competition.) In the case of changes to a previous year's robot system (not an entirely new design), explain how you arrived at your decision for these changes and focus the rest of the paper on the systems engineering work you performed to develop the new/updated subsystems/components and integrate them into the whole system to perform the mission. [2 points]</p> <p>3. <u>Major Reviews:</u> At a minimum, describe how you conducted the System Requirements Review (SRR), Preliminary Design Review (PDR), and Critical Design Review (CDR), and the changes that occurred to the system design, the schedule, the cost budget, and Technical Performance Measurements as a result of the external reviewers' comments at each review. [3 points]</p> <p>4. <u>Schedule of work:</u> Discuss the project schedule and how it evolved from inception to disposal of robot system. Show the original planned schedule before project start, and as a minimum the</p>	<p><b>8 points for 5 elements.</b></p> <p><b>2 bonus points may be awarded for exceptional work on Project Management Merit elements</b></p>

<p>actual final schedule, explaining what changed, why it changed, when it changed, and how the changes affected the cost budget and relevant technical requirements. When you go through a major review, it's not unusual for the schedule to change. Demonstrate in the discussion that the schedule was used to manage the project. [1 point]</p> <p>5. <u>Cost budget</u>: Discuss the cost budget for total project costs (including travel) and how it evolved from inception to disposal of robot system. Show the original estimated cost budget before project start, and as a minimum the actual final cost budget, explaining what changed, why it changed, when it changed, and how the changes affected the schedule and relevant technical requirements. When you go through a major review, it's not unusual for the cost budget to change. Demonstrate in the discussion that the cost budget was used to manage the project. [1 point]</p>	
<p><i>Systems Engineering Merit</i></p> <p>1. <u>Concept of Operations (ConOps)</u>: Describe how the robot system will be operated to meet stakeholder expectations and accomplish the robot system mission. Define the purpose of the project (needs, goals, and objectives); identify stakeholder expectations (wants and needs); define assumptions and constraints; determine your project boundaries (internal and external interfaces); define the operational phases and scenarios.</p> <p>2. <u>System Hierarchy</u>: Provide a top-down breakdown of the system design. Show that a new more detailed level in the hierarchy was the central topic reviewed and baselined at each control gate or major review (SRR, PDR, CDR).</p> <p>3. <u>Interfaces</u>: Identify the key important interfaces between elements in the system hierarchy at each system hierarchy level and their type (i.e. mechanical, electrical, human, signal, data, communication, etc.). Include key important external interfaces. Discuss how the interfaces possibly affected system design.</p> <p>4. <u>Requirements</u>: Identify the key driving requirements for robot system design, operations, interfaces, testing, safety, reliability, etc., stated in proper "shall" language. Address system and lower level derived requirements. These are the requirements that should specifically be addressed when you discuss verification – see Systems Engineering Merit element 8 "Verification of system meeting requirements."</p>	<p><b>8 points for 8 elements, one for each element.</b></p> <p><b>Up to 4 additional points for exceptional work and additional systems engineering methods used.</b></p>

<p>5. <u>Technical Performance Measurement:</u> Identify and discuss technical measures that are important to achieving your Design Optimization Criteria (for example: mass, power, data – any technical characteristic that you consider important, difficult to achieve, or particularly risky to project success), how they are allocated initially to system elements in the system hierarchy, and how that allocation changes as the system design evolves through verification. Demonstrate that the budgeting and management of these important technical quantities was used in the design process.</p> <p>6. <u>Trade Studies:</u> Discuss how important robot system decisions were made using trade studies, i.e., using weighted evaluation criteria scorings, with key decision results captured as robot system derived requirements.</p>	
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7. Engineering Specialties:

Discuss design and operations considerations that address the engineering specialties captured as key driving requirements

[e.g.,

- **Reliability** (what did you have to design into your system to assure that the system will operate properly until the end of the competition),
- **Maintainability** (what did you have to design into your system to assure that you can maintain and repair your system if it fails at the competition, and what tools you might need for repairs and maintenance),
- **Logistics** (what did you have to design into your system to assure that if you have a failure at the competition that you have on hand parts for repairs and maintenance, possibly bringing spare parts with you or finding parts sources local to the competition),
- **Transportability** (what did you have to design into your system to be able to transport your system to and from the competition in a working condition, including possibly design features and tools needed for easy disassembly for packing/transport/shipping and reassembly at the competition),
- **Safety** (what did you have to design into your system to assure that it cannot cause injury or damage during the mission from pack up to leave until return home and disposal)).

8. Verification of system meeting requirements:

Discuss how you assure or intend to assure that the as-built system satisfies, in the context of the concept of operations and under the environmental conditions of the competition, all of the key driving requirements identified and discussed in the section addressing Systems Engineering Merit element 4 “Requirements.” Discuss how the key important interfaces were verified or plan to be verified.



### 4.3 PUBLIC OUTREACH REPORT

Each team must participate in assisting one middle/high school student group in their local community with designing a technology demonstration that could be conducted inside NASA's Artemis Arenas. This project is designed to engage students in STEM (Science, Technology, Engineering and Math) by introducing students to robotics and coding through activities. Requirements for outreach activities:

- Reach students both in person in the classroom and remotely through telecommunications like you will from Mission Control to your robot in the Artemis Arena.
- Partner with your university's (STEM) education college or an educational organization if possible. The college of education may already be familiar with off-the-shelf educational robots (Examples include, but are not limited to: Spheros Bolts, Spheros RVR+, LEGO Mindstorms, etc.)
- Introduce students to STEM career possibilities. Share your STEM journey. What attracted you to engineering? How did you get involved? What are you getting out of participating in Lunabotics? What's next for you in your STEM career?
- Makes the connection between robotics, coding, the Artemis mission, and NASA careers.
- Showcase what they can do next. Highlight an existing program or activity related to robotics or the NASA education program in which students can participate next. See these [Artemis Student Challenges](#).

Meet students where they are at by finding out what they know and don't know. Keep in mind that not all students are familiar with or have access to robotics. They may not be experienced with writing simple instructions to go through a maze or navigating around obstacles in the Artemis Arena. Students may not know robotics clubs or competitions like Lunabotics exist. They may not realize that robotics and programming are possible STEM careers. As a Lunabotics university team, preparing your robot to successfully operate in the Artemis Arena to navigate and complete designated tasks will surely impress students. Hook the class by demonstrating your robot. Robotics captures the imagination! Your team will introduce STEM to classes in a tangible, exciting way that can make them realize that this could be something they can do too. This is your opportunity to reach back and inspire these students with your expertise on something that you are deeply knowledgeable about and love. Share that enthusiasm!

We are returning to the moon as a new generation of explorers, this time to stay. Outreach activities should capitalize on the excitement of NASA's Artemis mission to spark student interest and involvement in STEM and to create enthusiasm as we prepare for humanity's next giant leap, sending humans to mars. Make sure that you make the NASA connection when you do your outreach with students.

Each team must submit a report of the Outreach Project electronically in PDF. eastern time. A minimum score of 11 out of 15 possible points must be achieved to qualify to win in this category. In the case of a tie, the judges will choose the winning outreach project.



NASA's Lunabotics Competition Outreach Project Report Scoring Rubric	
Elements	Points
<p>Structure, Content and Intrinsic Merit:</p> <ul style="list-style-type: none"> <li>Formatted professionally, clearly organized, correct grammar and spelling, size 12 font; single spaced, maximum of 5 pages not including the cover. A link in the body of the report to a multimedia site with additional photos or videos is allowed. Cover page must include: team name, title of paper, full names of all team members, university name and faculty advisor's full name.</li> <li>Purpose for this outreach project, identify outreach recipient group(s), identify (STEM) educational college or organization partner.</li> <li>Pictures or video clips must appropriately demonstrate the outreach project (provide a link).</li> <li>An appendix report describing the activities used with students using the "5E model of instruction."</li> </ul>	<p>There are 4 points for 4 elements.</p>
<p>Educational Outreach Merit:</p> <ul style="list-style-type: none"> <li>The report must effectively use robotics and coding activities to reach middle/high school students in both the classroom and remotely using telecommunications.</li> <li>The report must identify the off-the-shelf robots used that could perform in the sand and regolith, the coding language featured, and the rationale behind these decisions.</li> <li>The appendix report must include activities using the <a href="#">5E model of instruction</a> to prepare students to use coding and robotics.</li> <li>Describe how the team prepared students to operate robots in the classroom versus sand versus simulate Lunar regolith?</li> <li>Describe how the team shared their STEM journey and demonstrated their robot. Explain how the team taught students about NASA's Artemis mission, In Situ Resource Utilization (ISRU), robotics activities they can get involved with in the future, and NASA STEM careers. Describe how you know students were inspired. Cite examples and data.</li> <li>The report describe how team partnered with (STEM) college of education or organization. How did you work together? What were the benefits of this partnership?</li> <li>The report must describe exactly how the Lunabotics Competition team participated, including the number of team members present and the number of hours each team member participated. How many partners helped? How many hours did the partners contribute?</li> </ul>	<p>There are 8 points for 8 elements.</p>

<ul style="list-style-type: none"> <li>The report must show statistics on the participants and activities. How many activities were taught? How many children were in the middle/high school group? Female/male students? Minority students?</li> </ul>	
<p>Additional points for exceptional work:</p> <ul style="list-style-type: none"> <li>The report included lessons learned from doing outreach activities and how the activities can be improved in the future.</li> <li>Creative use of telecommunications to reach students remotely nationally.</li> <li>The report identified how the team encouraged students to stay engaged in robotics and NASA after these outreach activities end.</li> </ul>	<p>There are 3 points for 3 elements.</p>

## NASA Resources

[Artemis](#)

[Forward to the Moon Explorer Activities](#)

[In-Situ Resource Utilization](#)

[Human Exploration and Operations](#)

[NASA's Next Generation STEM: Moon](#)

### **Hands-on Science Activities**

[Crew Transportation With Orion](#)

[Propulsion With the Space Launch System](#)

[Habitation With Gateway](#)

### **Videos**

[Get Ready for Artemis](#)

[Artemis I: We are Capable](#)

[Artemis I: NASA's Plans to Travel Beyond the Moon](#)

[NASA 2022: A Year of Innovation](#)

[Time-lapse of Core Stage Stacking for the Artemis I Mission](#)

[A 360 Look at the Artemis I Core Stage Lift and Mate](#)

[A 360 Look at the Artemis I launch vehicle stage adapter lift](#)

[STEMonstrations](#)



#### 4.4 PRESENTATIONS AND DEMONSTRATIONS

1. This is an optional event. You do not have to participate in this event, however, you will be ineligible to win the grand prize.
2. Teams choosing to compete in this event shall submit a complete Presentation and Demonstration slideshow electronically in one PDF file.
3. The Presentation and Demonstration is an optional category in the overall challenge and will be judged by a panel of NASA and private industry personnel. Each team will be allotted 25 minutes in front of the judging panel. It is expected that the presentation and demonstration will last approximately 20 minutes with an additional 5 minutes for questions and answers. There is a hard cut-off at the 25-minute mark in order to maintain the judging schedule.
4. The slides for the presentation must be submitted electronically in PDF file format. NASA will project these slides onto the screen during the presentation. Please note that updates and modification to slides are not possible after the deadline, as judges will pre-score the content.
5. Each subcomponent of the Scoring Elements will be ranked using an adjective rating system, with an “Excellent” score receiving full credit, “Very Good” receiving 70% credit, “Satisfactory” receiving 50% credit, “Marginal” receiving 20% credit, and “Unsatisfactory” receiving 0% credit. The “Excellent” rating is used to account for exceptional work (there are no bonus points this year). In case of a tie, the judges will choose the winning presentation. The judges’ decision is final.

##### *Notes on Demonstration*

1. Safety is of the utmost importance. You are expected to be aware of the specific hazards associated with your robot and plan safe practices for demonstration. Everyone shall adhere to safe practices at all times during the demonstration, especially when troubleshooting unexpected issues in real-time. A clear zone shall be established around the robot, and no one shall enter that zone while the robot is in operation. All content from this paragraph shall be addressed when presenting the “Safety plan” topic.
2. “Demonstration” defined: We prefer that you perform a live demonstration of all functions via the control system, however we recognize that this is not always possible. If parts or the entire robot cannot be controlled at the time of demonstration, it is acceptable to move parts by hand (once the power has been turned off), show video from practice runs, etc. to communicate the functionality and attributes of the system and/or subsystems.
3. Safety: Re-read the above note on safety, and plan how to safely handle the unexpected!

Scoring Rubric – Slide Presentation and Demonstration	
Element	Points
<p><i>Scoring Element 1: Individual Slides</i></p> <ol style="list-style-type: none"> <li>1. Judging Criteria               <ol style="list-style-type: none"> <li>a. Content, Formatting, and Illustrations: Each topic is addressed in sufficient depth. Include illustrations to support slide content (technical content, progression of the project, etc.). Ensure that formatting is readable and there is a good balance of text to graphics. Utilize proper grammar and spelling.</li> <li>b. Presenter’s Delivery: Body language, preparedness, slide handling, knowledgeable, passion, effective communication.</li> </ol> </li> <li>2. Topics to Cover               <ol style="list-style-type: none"> <li>a. Introduction                   <ol style="list-style-type: none"> <li>i. Include team name, university name, names of team members, and faculty advisor’s name.</li> </ol> </li> <li>b. Safety Plan                   <ol style="list-style-type: none"> <li>i. Robot-Specific Details: Discuss hazards and safety features.</li> <li>ii. Demonstration Safety: Discuss your plan for the demonstration. Include hazards that could be encountered during the demonstration and how you have addressed them to ensure a safe demonstration.</li> </ol> </li> <li>c. Project and System Performance Goals                   <ol style="list-style-type: none"> <li>i. Qualitative</li> <li>ii. Quantitative: Specify target values/ ranges</li> </ol> </li> <li>d. Project Management – Management of budget, schedule, team, risk, etc.</li> <li>e.) Design and Testing                   <ol style="list-style-type: none"> <li>i. General Philosophy and Process</li> <li>ii. System-level Alternatives Considered</li> <li>iii. Subsystem Alternative Analysis and Design Development (Mining, Mechanical, Electrical, Software and Controls)</li> <li>iv. Final Configuration</li> <li>v. Performance Testing (include comparison of testing results to goals)</li> </ol> </li> <li>f.) Innovation                   <ol style="list-style-type: none"> <li>i. Comparison to last year and evolution from previous years</li> <li>ii. Identify efforts to evolve processes, features, components, etc.</li> </ol> </li> </ol> </li> </ol>	<p><b>There are 15 base points for this element.</b></p> <p><b>Lack of “innovation” topic coverage will not count against teams in their first year at the challenge.</b></p>

<p><i>Scoring Element 2: Overall Package</i></p> <ol style="list-style-type: none"> <li>1. General organization and flow of the slides as a package</li> <li>2. General organization and flow between presenters. Time management: appropriate number of slides and material for time allotted and a professional cadence.</li> <li>3. Question and Answer session</li> <li>4. Overall Performance</li> </ol>	<p><b>There are 6 base points for this element.</b></p>
<p><i>Scoring Element 3: Demonstration</i></p> <p>Live demonstration will not be permitted if the “Demonstration Safety” component of the Safety Plan was not addressed prior to the intended movements.</p> <p>Scoring:</p> <ol style="list-style-type: none"> <li>1. Pass/Fail criteria: <ol style="list-style-type: none"> <li>a. Adherence to the safety plan.</li> <li>b. Executing the demonstration safely.</li> </ol> </li> <li>2. Extent of organization, integration, and planning</li> <li>3. Extent of demonstration</li> <li>4. Depth of explanation</li> </ol>	<p><b>There are 4 base points for this element.</b></p> <p><b>Failure to adhere to safe practices will automatically result in a score of “0” points.</b></p>





## 5. LUNAR ROBOTS

Components (i.e. electronic, mechanical, etc.) are not required to be space qualified for atmospheric, electromagnetic, thermal or Lunar environments.

### 5.1 ROBOT REQUIREMENTS

1. Be contained within a payload envelope of 1.1m length x 0.6m width x 0.6m height with a maximum mass of 80kg. It may deploy or expand beyond the envelop after the start of each attempt but may not exceed 1.5m in height.
2. A minimum of four (4) lifting points, safe for human hands and clearly marked (ISO 7000-1368) for students and NASA staff to use in a safe manner.
3. The launch volume dimensions of the robot may be oriented in any way (i.e. length, width, height - could be defined to be along any of the X, Y, Z axes) (dimensions correspond to the typical payload volume available on today's Lunar landers). The team must declare the robot orientation by length and width to the inspection judge.
4. Reference Point Arrow - must mark the forward direction of the mining robot in the starting position configuration (the reference location and arrow pointing forward can point in any direction of the team's choosing, except up). The judges will use this reference point and arrow to orient the mining robot in the randomly selected direction and position (you can use a permanent-type marker) indicating the team's choice of forward direction on any location on the robot is acceptable if multiple arrows do not conflict. The arrow does not have to indicate the robot's preferred forward direction. The arrow is used only to orientate the robot prior to starting the robot run to face the robot arrow either north, east, south, or west after spinning the direction wheel).
5. Subsystems used to transmit commands / data and video to the telerobotic operators are counted toward the mass limit. Equipment not on the robot used to receive data from and send commands to the robot for telerobotic operations is excluded from the mass limit.
6. Multiple robot systems are allowed, but the total mass and starting dimensions of the whole system must comply with the volumetric dimensions given in this rule.
7. The robot can run either by telerobotic (remote control) or in autonomous operations.
8. Run either by telerobotic (remote control) or autonomous operation.
9. Touch sensors are not allowed.
10. The "KILL SWITCH" – There is no waiver to this requirement. The robot shall be equipped with an easily accessible red emergency stop button or "Kill Switch" as follows: Use sound engineering practices and principles in placing the "Kill Switch" on your robot(s), failure to do so may result in a safety disqualification. The "Kill Switch" shall have a minimum diameter of 40 mm; it shall be located on the surface of the construction robot and require no additional steps to access it. Only one "Kill Switch" per robot and in the case of multiple robots, each robot will have its own "Kill Switch." It shall be easily accessible and activated in an easy and quick manner. Disabling the "Kill Switch" without authorization from the Staff shall result in a safety disqualification. The emergency stop button must stop the construction robot's motion and disable power with one push motion on the button. It must be highly reliable and instantaneous. For these reasons an unmodified "Commercial Off-The-Shelf" (COTS) red button is required. A closed control signal to a mechanical relay is allowed as long as it stays open to disable the robot. This rule exists in order to have the capability to safe the construction robot in the event of a fire or other mishap. The button should disconnect the batteries from all controllers (high current, forklift type button) and it should isolate the batteries from the rest of the active sub-systems as well. Only onboard laptop computers and data-logger(s) may stay powered on if powered by its own, independent, internal computer battery. For example: it is acceptable to have a small battery onboard that only powers a (ex:) Raspberry Pi

- (or equal) control computer, and whose power does not flow through the main robot kill switch.
11. The robot must provide its own onboard power. No facility power will be provided to the robot during the attempt. There are no power limitations except that the robot must be self-powered and included in the maximum mass limit. The energy consumed must be recorded with a “Commercial Off-The-Shelf” (COTS) electronic data logger device. Actual energy consumed during each attempt must be shown to the judges on the data logger immediately after the attempt) The ‘immediate’ part refers to the judge climbing into the arena, finding the logger and recording the power reading. If the logger is independently powered, then the robot can be remotely powered off after the run. Although this is acceptable, it is not recommended in case the robot needs to be commanded to complete an operation so that it can be removed from the arena.
  12. To ensure the robot is usable for an actual mission, it cannot employ any fundamental physical processes, gases, fluids or consumables that would not work in an off-world environment. For example, any dust removal from a lens or sensor must employ a physical process that would be suitable for the Lunar surface. Teams may use processes that require an Earth-like environment (e.g., oxygen, water) only if the system using the processes is designed to work in a Lunar environment and if such resources used by the robot are included in the mass of the robot. Closed pneumatic systems are allowed if the gas is supplied by the robot itself. Pneumatic systems are permitted if the gas is supplied by the robot and self-contained.
  13. Since budgets are limited, the rules are intended to require robots to show an off-world plausible system functionality but the components do not have to be traceable to an off-world qualified component version. Examples of allowable components are: Sealed Lead-Acid (SLA) or Nickel Metal Hydride (NiMH) batteries; composite materials; rubber or plastic parts; actively fan cooled electronics; motors with brushes; infrared sensors, inertial measurement units, and proximity detectors and/or Hall Effect sensors, but proceed at your own risk since BP-1 is very dusty and abrasive. Teams may use honeycomb structures as long as they are strong enough to be safe and the edges sealed to prevent dust intrusion, A wheel with a large honeycomb structures that is open on both sides is allowed as long as the edges are not so sharp that they would be a cutting hazard. Teams may not use GPS, rubber pneumatic tires; air/foam filled tires; open or closed cell foam, ultrasonic proximity sensors; or hydraulics because NASA does not anticipate the use of these on an off-world mission.



## 6. PROOF OF LIFE, ARENA AND OPERATIONS CRITERIA

### 1. PROOF OF LIFE

1. While NASA Kennedy Space Center is not able to offer an on-site competition expedience in 2023, the student teams are still expected to prove that they have built and operated an excavation robot that meets all of the 2023 Lunabotics requirements listed in this Guidebook and complies with their systems engineering design.
2. The culmination of all the systems engineering and project management work will be the fabrication and operation of a fully functional Lunabotics robot for excavating simulated icy regolith (gravel) buried below an overburden of regolith simulant.
3. All Lunabotics teams shall provide a "Proof of Life" video recording not to exceed 15 minutes in length and shall demonstrate a robot that can deploy, drive, excavate and deliver simulated icy regolith gravel to a simulated receiving hopper. The video recording shall have narration and a fully functional demonstration with an explanation of the concept of operations for mining simulated icy regolith.

### 2. ARENA

1. It is not expected that teams will use lunar regolith simulant for this demonstration. Use of construction sand or an outdoor beach volleyball sand court or any other sand area is an acceptable granular material for the purposes of this "proof of life" video. The "Proof of Life" video recording shall serve as a verification that the Lunabot is fully functioning.
2. The Lunabot shall drive on a simulated arena and excavate simulated icy regolith buried under an overburden of granular material, then it must return to the starting site and deliver the granular material to a simulated receiving hopper. The arena may be constructed from a sand granular material or an existing asset such as a beach volleyball sand court or any other sand area may be used.

More details are provided below:

1. The mining arena area is ~6.9m long and 2.5m wide.
  2. The excavation zone measures 2.5m long and 2.5m wide.  
(Reference Figure 1.)
  3. The collector sieve is 1.0m wide by 0.3m deep. The top lip of the sieve is 0.5m off the surface of the regolith.
3. The Mining Zone:
    1. Contains ~30cm of sand granular material over a ~15cm bed of rock gravel (icy regolith simulant). Gravel is only required at the excavation site for the Proof of Life video. The entire excavation zone does not need to have buried gravel.
    2. Larger rocks may also be mixed in with the sand/gravel in a random manner.  
(gravel is ~2cm in diameter)

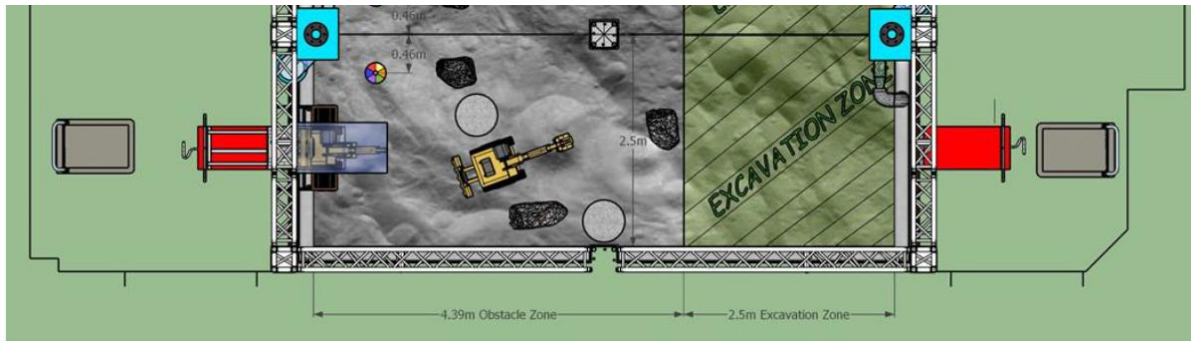


Figure 1: Dimensions of the Lunabotics “Proof of Life” Arena

4. Surface features will consist of craters on each side of the arena with randomly placed obstacles. The mining robot will be placed in the arena in a randomly selected starting position and direction.
5. There will be at least three (3) boulder obstacles placed on top of the BP-1 surface within the obstacle area before each competition attempt is made.
6. The placement of the boulder obstacles will be randomly selected before the start of the competition.
7. Each obstacle may have a diameter of approximately 30 cm to 40 cm and will have random heights.
8. There will be at least two (2) craters of varying depth and width, being no wider or deeper than 40 cm.
9. The sand may include naturally occurring rocks.

### 3. OPERATIONS CRITERIA

1. A mining robot may only excavate sand and gravel located in the respective mining zone at the opposite end of the mining arena from the starting zone. Mining is allowed as soon as the mining line is crossed by the front end of the robot.
2. The mining robot is required to move across the obstacle area to the mining zone and then move back to the collection area to deposit the sand and gravel into the collector sieve which shall be located in the starting zone at the far end of the arena border.
3. The mining robot cannot be anchored to the sand prior to the beginning of the proof of life demonstration
4. At the start of the proof of life demonstration, the mining robot may not occupy any location outside the defined starting position in the mining arena.
5. The mining robot must operate within the mining arena; it is not permitted to pass beyond the confines of the outside perimeter of the arena during the demonstration.
6. The gravel must be mined in the mining zone and deposited on the sieve frame. A team that excavates any material from the starting or obstacle areas will be disqualified.
7. The gravel must be carried from the mining zone to the sieve frame by any means and be deposited on the sieve in its raw state. A secondary container like a bag or box may not be deposited on the sieve. Depositing a container on the sieve will result in disqualification of the team.
8. The mining robot can separate itself intentionally, if desired, but all parts of the mining robot must be under the team’s control at all times. The robot does not have to re-assemble prior to the end of the competition run.
9. The mining robot may not use any process that causes the physical or chemical properties of the sand to be changed or otherwise endangers the uniformity between competition attempts. The mining robot may not penetrate the sand surface with more force than the weight of the mining robot before the start of each competition attempt.
10. No ordnance, projectile, far-reaching mechanism, etc. may be used. The mining robot must move

on the sand surface.

11. All rock/gravel will be sieved out from the sand at the collector sieve and weighed separately. A navigational aid system may be attached to the collector sieve frame but it shall not be higher than 0.25 m above the sieve frame, and cannot be permanently attached or cause alterations (ex: no drilling, nails, screws, etc.).
12. Beacons or targets may be attached to the collector sieve frame for navigation purposes only. Tape, clamps or gravity may be used but screws may not be used to hold the devices in place. This navigational aid system must be attached during the setup time and removed afterwards during the removal time. If attached to the sieve frame, it must not exceed the length of the frame and not weigh over 4 kg.
13. Teams can attach targets to the front of the collector sieve as long as the attached target does not interfere with sliding the sieve back along the two side support rails. In other words, keep the target under 90 cm wide.
14. The mass of the navigational aid system is included in the maximum mining robot mass limit of and must be self-powered. A video recording of the Lunabot mining robot being weighed on a scale shall be provided in the Proof of Life video. The team faculty member is required to supervise this weighing operation and shall appear on the video certifying that the weight is correct and meets the 80 kg limit. The dimensions of the Lunabot shall also be certified in the video recording by the faculty member by showing in the video that the dimensions have been verified with a measuring tape.
15. The target/beacon may send a signal or light beam or use a laser based detection system which have not been modified (optics or power). Only Class I or Class II laser or low powered lasers (< 5mW) are allowed. Supporting documentation from the laser instrumentation vendor must be provided to the responsible faculty member for “eye-safe” lasers.
16. Inertial measurement units (IMU) are allowed on the mining robot. Teams have to explain to in the Proof of Life video how the compass feature will be switched off or the compass data is subtracted to ensure the internal calculations do not make use of the compass (from any magnetic field surrounding the robot).
17. Global Positioning Satellite (GPS) or IMU-enabled GPS devices are not allowed. Teams have to explain in the Proof of Life video how the device will be switched off or the data is subtracted and ensure the internal calculations do not make use of the GPS or IMU-enabled GPS device.
18. The team must declare the robot orientation in the Proof of Life video. An arrow on the reference point (the reference location and arrow pointing forward can be any point and direction of the team's choosing, except up) must mark the forward direction of the mining robot in the starting position configuration.
19. Autonomous robot operations are highly encouraged but not required. If autonomy is attempted, then a narrated explanation shall be provided in the Proof of Life video. Achieving autonomy will be a favorable consideration in the awarding of ‘Proof of Life’ points.
20. Upon completion of the “Proof of Life” Lunabot simulated icy regolith mining operations, the responsible faculty member shall supervise and certify a weighing of the mass of gravel, in kilograms, collected in the receiving sieve. This amount shall be reported in the “Proof of Life” video recording by this faculty member.



## 7. AWARDS

### 1. The Judges Innovation Award

Awarded to the team with best design based on creative construction, innovative technology and overall architecture.

### 2. Systems Engineering Paper Award

Papers should discuss the Systems Engineering (SE) methods used to design and build the mining robot. The purpose of the SE paper is to encourage the teams to use the SE process while designing, building and testing their robots.

### 3. Presentation and Demonstration Award

The presentation component provides the teams with the opportunity to present the spirit, intent and technical outcome of their design project. This allows the students to develop their presentation and public speaking skills, which will serve them in thesis defense and / or dissertations, grant requests, job interviews, etc.

### 4. Public Outreach Report Award

Teams must report the type of STEM outreach they have completed in their communities, the activities they provided, and the numbers they reached.

### 5. The Joe Kosmo Award for Excellence – Grand Prize

Awarded to the team that scores the most points in all challenge events. Joseph Kosmo graduated from Pennsylvania State University in 1961 with a bachelor of science in aeronautical engineering and began his career with the NASA Space Task Group in the Crew Systems Division, working on the Mercury Program spacesuit. During the past 45 years, he has participated in the design, development, and testing of Mercury, Gemini, Apollo, Skylab, and Space Shuttle spacesuits, as well as numerous advanced technology configuration spacesuits and EVA gloves for future mission applications. Kosmo received the American Astronautical Society's Victor A. Prather Award, the NASA Exceptional Service Medal, and the Astronaut Silver Snoopy Award. He has pursued the development of advanced spacesuits, gloves, and ancillary EVA-supporting hardware concepts for future planetary surface exploration. In 2011, he retired from NASA after a 50-year career in the space industry. This award honors his service and contributions to America's space program.

### 6. Award Summary

Scholarship Awards	
Systems Engineering Paper - 1st Place	\$3,000
Systems Engineering Paper - 2nd Place	\$2,000
Systems Engineering Paper - 3rd Place	\$1,000
Presentation and Demonstration - 1st Place	\$3,000
Presentation and Demonstration - 2nd Place	\$2,000
Presentation and Demonstration - 3rd Place	\$1,000



Outreach Project Report- 1st Place	\$3,000
Outreach Project Report- 2nd Place	\$2,000
Outreach Project Report- 3rd Place	\$1,000
Grand Prize	\$5,000
Grand Prize - 1st Runner Up	\$3,000
Grand Prize - 2nd Runner Up	\$2,000



## APPENDIX A. NASA GATEWAY TEAM APPLICATION INSTRUCTIONS

### Team Application Instructions

**WARNING:**

Please carefully select the person that will be submitting your team application. The person who creates the application is the person who will receive all official notices (IE acceptance letter, rejection letter, etc.), and will be responsible for uploading deliverables throughout the project. These responsibilities CANNOT be assigned to others in the Gateway system. Furthermore, the creator of the application cannot be changed after submission. It should be noted that while the application does ask for both a “Team Lead” and a “Faculty Member”, these fields are datapoints only, and does not replace any of the responsibilities held by the creator of the application.



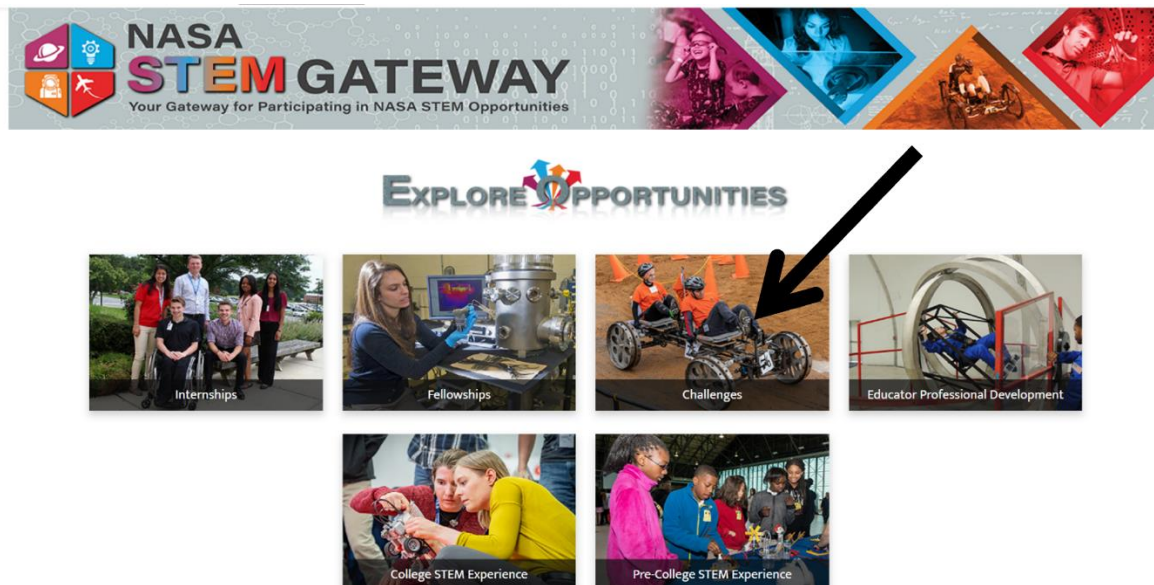
## How to Register Your Team in Gateway

To be considered for participation in the 2023 Lunabotics competition you will have to complete a Team Registration in [NASA STEM Gateway](#). This is a very important step as the Team lead will have to create an application and then invite the rest of the team including the faculty advisor. The person that creates the team application will be responsible for uploading all required documentation and deliverables throughout the competition. This person cannot be changed, so please make sure whoever submits the team application is the person you want to receive official communication and be responsible for uploading deliverables.


1. Once you enter the page from [NASA STEM Gateway](#) select “Explore Opportunities”



2. Then select “Challenges”



### 3. Select Lunabotics 2023



**NASA STEM GATEWAY**  
Your Gateway for Participating in NASA STEM Opportunities

# CHALLENGES

Visit <https://www.nasa.gov/stem> for more information on the NASA Challenges


Challenges ▾

2 Items • Sorted by Physical Location • Filtered by All engagement openings • 5 more filters applied

Search this list...

	Unique Identification N...	Short Title	Physical Location	Session	Eligible Applicant(s)	Activity Type	Registration End Date
1	013355	Lunabotics 2023	Kennedy Space Center	Lunabotics 2023	Student and Educator	Virtual	10/19/2022
2	012900	HERC 2023	U.S. Space and Rocket Center	HERC 2023	Student and Educator	In-person / Virtual	10/6/2022

### 4. Select "Apply Now"



**NASA STEM GATEWAY**  
Your Gateway for Participating in NASA STEM Opportunities

Engagement Opening  
**Lunabotics 2023**

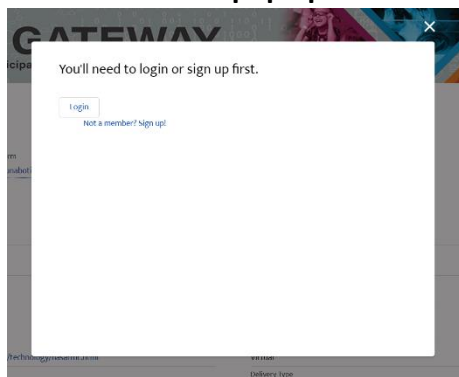
Course: LUNABOTICS  
Record Type: Challenges  
Term: Lunabotics 2023

Apply Now

Course: LUNABOTICS  
Unique Identification Number: 013355  
Short Title: Lunabotics 2023  
Long Title: Lunabotics 2023  
Activity URI: <https://www.nasa.gov/offices/education/centers/kennedy/technology/nasarmc.html>  
Application Type: Application

Term: Lunabotics 2023  
Eligible Applicant(s): Student and Educator  
Registration Start Date: 7/15/2022  
Registration End Date: 10/19/2022  
Activity Type: Virtual  
Delivery Type: NASA Delivered

### 5. This window will pop up



6. If Team Lead already has a profile in Gateway (from a previous NASA engagement) please log in with the Username and password you used previously and go to step 17. If this is the first time continue to next step:

### Select your Category

#### Which category best represents you?

Hover over each category for more information and then click the user type that best describes you.

**Active Student**

**Educator**

**Other**

### ACTIVE STUDENT

Choose this category if you are *actively* attending one of the following as a student:

- High School (*formal or homeschooled*)
- Junior College
- Community College
- College
- University

By selecting this category, the system will allow you to personally

### 7. Fill out the requested information

Make sure all information is entered correctly and that you select the correct age range. **NASA requires all Lunabotics participants to be 18 years or over. If you are not at least 18 you are ineligible to participate.**

**Tell us a little bit about yourself**

\* First Name  
Robert

\* Last Name  
Builder

\* Email  
bobbybuilder23@yahoo.com

\* Age  
18 or over

Back Submit

## 8. Follow the “Next Steps...”

### Next Steps...

1. Check your inbox for the email address you just entered. You should receive a message from [hq-nasa-stem-gateway@mail.nasa.gov](mailto:hq-nasa-stem-gateway@mail.nasa.gov)
2. When you've logged in, you'll be directed to your profile where you will register your account.
3. Once your profile has been completed, you may apply to the available opportunities and track the status of your applications within NASA STEM Gateway.

Close

## 9. Once you click on the link provided in the email, click “Next”



bobbybuilder23@yahoo.com [Log Out](#)

By accessing and using this information system, you acknowledge and consent to the following:

You are accessing a U.S. Government information system, which includes: (1) this computer; (2) this computer network; (3) all computers connected to this network including end user systems; (4) all devices and storage media attached to this network or to any computer on this network; and (5) cloud and remote information services. This information system is provided for U.S. Government-authorized use only. You have no reasonable expectation of privacy regarding any communication transmitted through or data stored on this information system. At any time, and for any lawful purpose, the U.S. Government may monitor, intercept, search, and seize any communication or data transiting, stored on, or traveling to or from this information system. You are NOT authorized to process classified information on this information system. Unauthorized or improper use of this system may result in suspension or loss of access privileges, disciplinary action, and civil and/or criminal penalties.

Next

## 10. Create your password by following the minimum requirements



### Change Your Password

Enter a new password for  
**bobbybuilder23@yahoo.com**. Make sure to include at least:

☐ 12 characters

Also include at least 3 of the following:

☐ 1 uppercase letter

☐ 1 lowercase letter

☐ 1 number

☐ 1 special character ⓘ

\* New Password

.....

\* Confirm New Password

Change Password

## 11. Fill out your personal information

We'll need the following Personal Information to complete your Profile:

\* Date of Birth

Aug 6, 2004

Address

Country

United States

Street

City

State/Province

Florida

Zip/Postal Code

\* Phone

Complete this field.

\* Is this a Mobile Phone?

Yes

\* Is it okay to text you at the cell phone number above about your application?

No

Alternate Phone (Optional)

Next

## 12. Fill out Demographic information

Demographic Info

Completion of your Demographic Information is voluntary. No selection decisions are made based on the information. It will not adversely affect your application if you choose to not provide this information. Select the 'Do not wish to provide' option for each item that you choose not to report on.

\* Gender

-- None --

\* Ethnicity ⓘ

-- None --

\* Race (select one or more): ⓘ

American Indian or Alaska Native

Asian

Black or African American

Native Hawaiian or Other Pacific Islander

White

\* Are you a Veteran?

-- None --

\* Do you have a disability? ⓘ

-- None --

Identifying any qualifying disability is protected under the Americans with Disabilities Act Citizenship or the Rehabilitation Act of 1973.

Next

## 13. Fill out Citizenship

Citizenship

\* Citizenship

-- None --

Previous Next



NASA - National Aeronautics and Space Administration



INSPIRE - ENGAGE - EDUCATE - EMPLOY  
The Next Generation of Explorers

Related Links [No Fear Act](#) | [FOIA](#) | [PRA](#) | [Privacy](#) | [OIG](#) | [Agency Financial Reports](#) | [Help](#)

## 14. Enter “applicant type”, Grade Level” and “Academic Institution”

Education or Affiliate Organization

Please search for your institution's name below. Only the top 5 results will appear in the preview. If you do not see your institution please select "Show All Results" and continue your search in the full view. In this view you can search by your institution's name, address, phone, or website.

If you still cannot find your institution, please return to this page and select the "Can't find my institution" checkbox and enter your institution's information directly.

\* Applicant Type

-- None --

\* Search for your Academic Institution

Search Accounts...

Complete this field.

☐ Can't find my institution.

\* This can be a Junior College, Community College, College, University, High School, Middle or Elementary School, Museum, Science Center, Planetarium, or Youth Serving Organization

☐ I am registering for opportunities on behalf of a minor (younger than 14)

Previous Next

## 15. Fill out Authorization for Media Release

### Authorization for NASA Media Release

I hereby give my permission to be interviewed, photographed, and/or videotaped by NASA or its representatives in connection with a NASA production.

I understand and agree that the text, photographs, and/or videotapes thereof containing my name, likeness, and voice, including transcripts thereof, may be used in the production of instructional, promotional materials, and for other purposes that NASA deems appropriate and that such materials may be distributed to the public and displayed publicly one or more times and in different formats, including but not limited to, websites, cablecasting, broadcasting, and other forms of transmission to the public. I also understand that this permission to use the text, photographs, videotapes, and name in such material is not limited in time and that I will not receive any compensation for granting this permission.

I understand that NASA has no obligation to use my name, likeness, or voice in the materials it produces, but if NASA so decides to use them, I acknowledge that it may edit such materials. I hereby waive the right to inspect or approve any such use, either in advance or following distribution or display.

I hereby unconditionally release NASA and its representatives from any and all claims and demands arising out of the activities authorized under the terms of this agreement.

**YES**, by making this selection, I represent that I am of legal age, have full legal capacity, and agree that I will not revoke or deny this agreement at any time. I have read the foregoing and fully understand its contents.

**NO**, NASA does not have my consent to be interviewed, photographed, and/or videotaped by NASA or its representatives.

\* Please select your acknowledgement response below:

- ☐ YES  
☐ NO

I authorize NASA to collect and report data about my participation in STEM Engagement opportunities for continuous improvement purposes

\* Please select your acknowledgement response below:

- ☐ YES  
☐ NO

For information about NASA STEM Engagement, you may visit <https://www.nasa.gov/stem>

Previous

Next

## 16. Now you can click “Next” to apply for the challenge

Congratulations, you have completed your profile!

To complete your application, please click the "Apply Now" button on the following screen.

Next



NASA - National Aeronautics and Space Administration



INSPIRE-ENGAGE-EDUCATE-EMPLOY  
The Next Generation of Explorers

Related Links [No Fear Act](#) | [FOIA](#) | [PRA](#) | [Privacy](#) | [OIG](#) | [Agency Financial Reports](#) | [Help](#)

## 17. This will take you to the Lunabotics 2023 page. Click on “Apply Now”

Engagement Opening  
Lunabotics 2023

+ Follow

Apply Now

Printable View

Course  
[LUNABOTICS](#)

Record Type  
Challenges

Term  
[Lunabotics 2023](#)

Course  
[LUNABOTICS](#)

Unique Identification Number  
013355

Short Title  
Lunabotics 2023

Long Title

Award  
[Lunabotics 2023](#)

Activity URL  
<https://www.nasa.gov/offices/education/centers/kennedy/technology/nasarmc.html>

Application Type  
Application

Term  
[Lunabotics 2023](#)

Citizenship Restriction  
None

Eligible Countries

Eligible Applicant(s)  
Student and Educator

Registration Start Date  
7/15/2022

Registration End Date  
10/19/2022

Activity Type  
Virtual

Delivery Type  
NASA Delivered



**From this point all fields are required to be able to properly proceed forward**

### 18. Enter your institution's information

Please look carefully for your institution in the auto populate list. Almost every school is in the database. If you can't find your institution, consider entering slight variations such as hyphens, order of words, campus name, etc. This can increase the likelihood that you find your correct institution.

The screenshot shows the 'Institution Information' step of the application process. At the top, there's a header with the application ID 'APP-1013899' and buttons for '+ Follow', 'Withdraw Application', and 'Printable View'. Below this is a progress bar with steps: Incomplete (active), Submitted, Pending Offer, Accepted Offer, Declined Offer, Offer Expired, and Withdrawn. The main form area has a sub-progress bar with steps: Institution Info (active), Team Information, Team Member, Proposal, Supporting Doc, Interest, Review & Submit, and Submitted. The 'Institution Information' section includes a search bar for 'Lead Institution' with a placeholder 'Search Accounts...', a checkbox for 'Can't find my institution', and radio buttons for 'Do you have any Participating Institutions to add?' (Yes/No). A 'Next' button is at the bottom right. On the right side, there's a section for 'Invite Participant or Team Member(s)' with a table for adding members and a 'Send Invite(s)' button. Below this are sections for 'Team Member Applications (0)' and 'Engagement Affiliations (0)'.

### 19. Enter your Team's information, make yourself the lead and re-enter your information, enter Faculty's information. All fields MUST be filled out

The screenshot shows the 'Team Information' step of the application process. The main form area has a sub-progress bar with steps: Institution Info, Team Information (active), Team Member, Proposal, Supporting Doc, Interest, Review & Submit, and Submitted. The 'Team Information' section includes fields for 'Team Name', 'Faculty Advisor Name' (First Name, Last Name), 'Faculty Advisor Email' (with a red border and 'Complete this field.' message), 'Faculty Advisor Phone', 'Team Lead Name' (First Name, Last Name), 'Team Lead Email' (with a red border and 'Complete this field.' message), and 'Team Lead Phone'. A 'Next' button is at the bottom right. On the right side, there's a section for 'Invite Participant or Team Member(s)' with a table for adding members and a 'Send Invite(s)' button. Below this are sections for 'Team Member Applications (0)', 'Engagement Affiliations (1)' (showing a table with one entry: ENAF-0003084, University of Wisco..., Lead Institution), 'Proposals (0)', and 'Files (0)' with an 'Add Files' button and an 'Upload Files' button.



**20. Add your team members and also add your Faculty member. Don't worry if you miss any team members, you will be able to enter them once you complete application. Make sure to click "send invites" before you click next otherwise your invites will not be sent.**

**Team Member**

Invite Participant or Team Member(s)

#	FIRST NAME	LAST NAME	EMAIL
1			

[Send Invite\(s\)](#)

[Next](#)

**Invite Participant or Team Member(s)**

#	FIRST NAME	LAST NAME	EMAIL
1			

[Send Invite\(s\)](#)

**Team Member Applications (0)**

**Engagement Affiliations (1)**

Engagement Affi...	Account	Type
--------------------	---------	------

**21. DO NOT upload anything on the Proposal page just check "no" and click next**

**Proposal**

\*Do you have a proposal to upload?

☐ Yes

☒ No

[Next](#)

**Invite Participant or Team Member(s)**

#	FIRST NAME	LAST NAME	EMAIL
1			

[Send Invite\(s\)](#)

**Team Member Applications (0)**

**22. DO NOT upload any "Supporting Documents" at this time**

**Supporting Documents**

Upload your Supporting Documents (Word, PDF or image)

[Upload Files](#) Or drop files

[Next](#)

**Invite Participant or Team Member(s)**

#	FIRST NAME	LAST NAME	EMAIL
1			

[Send Invite\(s\)](#)

**Team Member Applications (0)**

## 23. Fill out the “how did you hear about us”

✓

✓

✓

✓

✓

Interest

Review & Submit

Submitted

### How Did You Hear About Us

\*How did you learn about this NASA STEM Engagement Opportunity? (Please check all that apply)

- ☐ Webinar
- ☐ Video/Promotional Video
- ☐ Social Media/News Release
- ☐ Friend/Family/Coworker
- ☐ Other NASA Engagement Opportunity/Event
- ☐ Email/Phone Call
- ☐ Online Search
- ☐ Capstone Project Search
- ☐ Faculty/Educator
- ☐ NASA Express
- ☐ Newsletter/Flyer
- ☐ Television/NASA TV
- ☐ Article/Publication
- ☐ Another Company's Website
- ☐ NASA Employee/Intern
- ☐ Other/Not Listed

Next

### Invite Participant or Team Member(s)

#	FIRST NAME	LAST NAME	EMAIL	
1	<input type="text"/>	<input type="text"/>	<input type="text"/>	+

Send Invite(s)

Team Member Applications (0)

Engagement Affiliations (1)

Engagement Affi...	Account	Type
ENAF-0003084	University of Wisco...	Lead Institution

View All

Proposals (0)

New

## 24. Review and Submit

✓

✓

✓

✓

✓

✓

Review & Submit

Submitted

### Review & Submit

Review the information you have entered and verify that it is accurate to the best of your knowledge. Clicking Next on this page will submit your application/registration. Be sure to review your entries in the section in addition to the sections that may appear to the right or below the Next button - Team Members, Engagement Affiliations (Participating Institutions), Proposal, and Files (Supporting Documents). If you have entered the information to your satisfaction, submit your application/registration. By submitting this application/registration, you certify that the information provided is true and correct.

\* Application Date

Aug 11, 2022

\* Team Name

Titan Towers

Team Lead

First Name

Zeeshan

Last Name

Patel

Email

zmanspace2001@gmail.com

Phone

920-739-1122

Faculty Advisor

First Name

Paul

Last Name

Dryer

### Invite Participant or Team Member(s)

#	FIRST NAME	LAST NAME	EMAIL	
1	<input type="text"/>	<input type="text"/>	<input type="text"/>	+

Send Invite(s)

Team Member Applications (0)

Engagement Affiliations (1)

Engagement Affi...	Account	Type
ENAF-0003084	University of Wisco...	Lead Institution

View All

Proposals (0)

New

Files (0)

Add Files

Upload Files

Or drop files

✓

✓

Submitted

Pending Offer

Accepted Offer

Declined Offer

Offer Expired

Withdrawn

Thank you for your submission.  
You may now navigate away from this page.

### Invite Participant or Team Member(s)

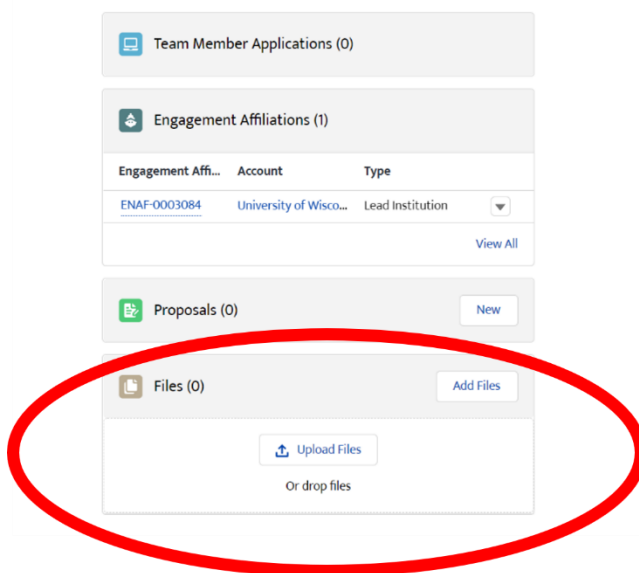
#	FIRST NAME	LAST NAME	EMAIL	
1	<input type="text"/>	<input type="text"/>	<input type="text"/>	+

Send Invite(s)

**25. Now you can upload your required application documents. You have the option to upload now, or at a later time, provided it is done before the deadline in the Guidebook.**

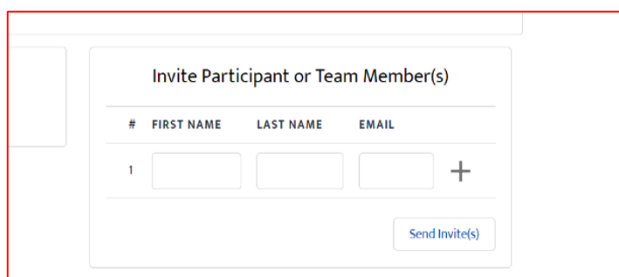
- a. (1) Statement from Supervising Faculty; and (2) Statement of Rights of Use. Together as one PDF file
  - i. Use the name format" **School Name\_DOCS**" It is important to use this exact format so reviewers can properly locate your submission in the database
- b. Project Management Plan (one PDF document). Please see instructions regarding required PMP content found in section 4.1 of the Guidebook
  - i. Use the name format "**School Name\_PMP**" It is important to use this exact format so reviewers can properly locate your PMP submission in the database

**Go to the bottom of the page to the "Files" section and upload the files separately**



The screenshot shows a vertical stack of four panels in the NASA Gateway system. The panels are: 'Team Member Applications (0)', 'Engagement Affiliations (1)', 'Proposals (0)', and 'Files (0)'. The 'Files (0)' panel is highlighted with a red oval. It contains an 'Add Files' button, an 'Upload Files' button with a cloud icon, and the text 'Or drop files'.

- 26. You can always add team members by going to the "Invite Participants or Team Member(s)" section. Remember to add your Faculty as a member of the team even if you list them in the original application field. A Faculty member is only officially linked to your team if they have been invited via the "Invite Participants or Team Members"**



The screenshot shows the 'Invite Participant or Team Member(s)' form. It has a table with columns: '#', 'FIRST NAME', 'LAST NAME', 'EMAIL', and a '+' icon. There is one row with the number '1' in the first column and empty input fields for the others. Below the table is a 'Send Invite(s)' button.

If you have any questions concerning the technical aspects of using the NASA Gateway system please contact the NASA Gateway helpdesk at: [hq-nasa-stem-gateway@mail.nasa.gov](mailto:hq-nasa-stem-gateway@mail.nasa.gov)

**\*\*\* End of Guidebook \*\*\***

***From Google Scholar ...***

Nasa Lunabotics Robotic Mining Competition 10th Anniversary (2010-2019): Taxonomy Technology Review  
<https://ntrs.nasa.gov/citations/20200003009>

Novel Approaches to Drilling and Excavation on the Moon  
<https://arc.aiaa.org/doi/pdf/10.2514/6.2009-6431>

Preparing for Mars: Evolvable Mars Campaign “Proving Ground” approach  
<https://ieeexplore.ieee.org/abstract/document/7119274>

NASA Human Spaceflight Architecture Team: Lunar Surface Exploration Strategies  
<https://ntrs.nasa.gov/citations/20120008182>

NASA Centennial Challenge: 3D-Printed Habitat  
<https://ntrs.nasa.gov/api/citations/20170009010/downloads/20170009010.pdf>

Lunar Spaceport: Construction of Lunar Landing & Launch Pads  
<https://commons.erau.edu/cgi/viewcontent.cgi?article=1017&context=spaceport-summit>

TOWARDS IN-SITU MANUFACTURE OF MAGNETIC DEVICES FROM RARE EARTH MATERIALS MINED FROM  
ASTEROIDS  
[https://robotics.estec.esa.int/i-SAIRAS/isairas2018/Papers/Session%2010c/1\\_iSAIRAS\\_Ellery\\_2018\\_final-11-40-Ellery-Alex.pdf](https://robotics.estec.esa.int/i-SAIRAS/isairas2018/Papers/Session%2010c/1_iSAIRAS_Ellery_2018_final-11-40-Ellery-Alex.pdf)

NASA Centennial Challenge: 3D Printed Habitat, Phase 3 Final Results  
<https://ntrs.nasa.gov/citations/20190032473>

A Process Plant for Producing Rocket Fuel From Lunar Ice  
<https://asmedigitalcollection.asme.org/IMECE/proceedings-abstract/IMECE2019/V006T06A108/1073266>

Robotic Construction on the Moon  
<https://ntrs.nasa.gov/api/citations/20210018912/downloads/Design%20for%20Robotic%20Construction%20on%20the%20Moon%20ISU%20SSP%2021%20STRIVES.pdf>

ISRU: The Basalt Economy.  
[https://www.researchgate.net/profile/Rodrigo-Romo-2/publication/322567782\\_ISRU\\_The\\_Basalt\\_Economy/links/5a5fff9c458515b4377b89cb/ISRU-The-Basalt-Economy.pdf](https://www.researchgate.net/profile/Rodrigo-Romo-2/publication/322567782_ISRU_The_Basalt_Economy/links/5a5fff9c458515b4377b89cb/ISRU-The-Basalt-Economy.pdf)

RASSOR - Regolith Advanced Surface Systems Operations Robot  
<https://ntrs.nasa.gov/citations/20150022134>

Building a Vertical Take Off and Landing Pad Using in situ Materials  
<http://ssi.org/2010/SM14-proceedings/Building-a-Vertical-Take-Off-and-Landing-Pad-using-in-situ-Materials-Hintze.pdf>

Mars Water In-Situ Resource Utilization (ISRU) Planning (M-WIP) Study

[https://mepag.jpl.nasa.gov/reports/Mars\\_Water\\_ISRU\\_Study.pdf](https://mepag.jpl.nasa.gov/reports/Mars_Water_ISRU_Study.pdf)

Affordable, Rapid Bootstrapping of the Space Industry and Solar System Civilization

<https://arxiv.org/abs/1612.03238>

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